# Faculty of Electrical Engineering

# REDUCTION OF HARMONIC USING SINGLE PHASE SHUNT ACTIVE FILTER BASED ON P-Q THEORY METHOD FOR PWM CASCADED MULTILEVEL INVERTER

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**DECLARATION**

“ I hereby declared that this report is a result of my own work except for the experts thst have been cited clearly in the references”

Signature :___________________________

Name : SABIQ SAFIUDDIN BIN MOHAMAD

Date : ___/___/2016

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# DECLARATION

"I hereby declared that I have read through this report entitle Reduction of Harmonic using Single Phase Shunt Active Filter Based on p-q theory method for PWM Cascaded Multilevel Inverter"

Signature :___________________________

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Date : ___/___/2016

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## ABSTACT

In recent years the extreme used of power electronic converters and other non-linear loads in industry deteriorates the power systems voltage and current waveforms. The use of nonlinear loads and power electronic circuit in power systems are grow rapidly. Examples are thyristor controlled inductors, converters for High Voltage Direct Current (HVDC) transmission and large adjustable speed drives. All of these loads created unwanted currents into the power system. The impact of harmonic caused more power losses, shorten device life time, and undermine the accuracy of protection and instrumentation device on the system. For higher power applications, multilevel inverter (MLI) structures have the particular advantages of operation at high DC bus voltages which can be achieved by using series connection of switching devices. However, conjunction in designing inverter, it is better to install active power filter such a way to mitigate the harmonic generated by other nonlinear load in the system. For this project, active power filter (APF) helps to enhance the quality of the distorted current waveform produced by the nonlinear load. The performance of APF based on instantaneous power theory control strategies is used and combined with MLI. The detailed analysis and evaluate the performance of APF with p-q theory is based on mathematical method p-q theory equation to generating reference current of shunt APF .The system is validated through extensive MATLAB-SIMULINK Tool Box to analyze the output waveform in term of total harmonic distortion (THD) of current and voltage. Based on result from simulation, by injecting current from APF to the line the THD is decreased in range 4% to 98%.



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## ABSTRAK


Dalam tahun kebelakangan ini, penggunaan penukar elektronik dan beban bukan linear yang melampau dalam industri mengakibatkan kerosotangelombang kuasa sistem voltan dan arus semasa. Penggunaan beban tidak linear dan kuasa litar elektronik di dalam sistem kuasa sedang berkembang pesat. Contohnya adalah thyristor mengawal pengaruh, penukar untuk penghantaran kuassa tinggi dan pemacu kelajuan boleh laras. Kesemua beban ini mencipta arus yang tidak diingini ke dalam sistem kuasa. Kesan harmonik menyebabkan lebih kerugian lebih kuasa, memendekkan jangka hayat peranti, dan melemahkan ketepatan perlindungan dan alat peranti pada sistem. Bagi applikasi kuasa yang lebih tinggi, inverter bertingkat (MLI) struktur ini mempunyai kelebihan tertentu seperti operasinya pada voltan bas DC yang boleh dicapai dengan menggunakan sambungan siri peranti pensuisan. Walau bagaimanapun, dengan adanya reka bentuk inverter, ia adalah lebih baik untuk memasang kuasa penapis aktif dengan cara ini ia dapat mengurangkan harmonik yang dihasilkan oleh beban tidak linear dalam sistem. Untuk projek ini, penapis kuasa aktif (APF) membantu meningkatkan kualiti bentuk gelombang yang dihasilkan oleh beban tidak linear. Prestasi APF berdasarkan strategi kawalan teori kuasa serta-merta dan digabungkan dengan MLI. Analisis terperinci dan menilai prestasi APF dengan teori pq adalah berdasarkan kaedah matematik dan persamaan teori pq untuk menjana arus rujukan untuk sistem pirau APF . Sistem ini disahkan melalui penggunaan MATLAB SIMULINK-Tool Box untuk menganalisis gelombang keluaran dari segi jumlah herotan harmonik (THD) arus dan voltan. Berdasarkan hasil dari simulasi, dengan menyuntik arus dari APF ke laluan arus jumlah THD itu menurun dalam julat 4% sehingga 98%.




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# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

In a modern electrical distribution system, there are extensive of used nonlinear electronic load such as power supplies, rectifier equipment, domestic application, adjustable speed drive, etc. One of the most problems associated with nonlinear electronic load is a nonlinear characteristic. These nonlinear loads produce non-sinusoidal current and voltage called harmonic distortion. The present of harmonic distortion can cause many problems such as transmission power losses, conductor overheating, over loading of capacitor bank, low power factor and etc [1]. This problem will make suffered in payment of electricity bills because of power quality issues. Over a last few years, there was many effort have been made in improving the harmonic distortion in power system distribution. A traditional method to improve harmonic distortion is by using passive filter (PPF). PPF is able to mitigate the harmonic component and improve power quality of electrical power system. However, the performance of passive filter is not satisfied although the cost is acceptable. This is because passive filter has many disadvantages due to capable to eliminated higher frequency harmonic, resonance problem, mistuning of passive element and instability in operation [2].


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Therefore, a dynamic, versatile and viable solution to mitigate the non-sinusoidal current produce by nonlinear load is active power filter (APF).  The use of APF is a trend of harmonic improvement in distribution power system because of its excellent characteristic. APF divided in two categories which is series and shunt filter. Generally, series APF used to generate harmonic voltage to compensate load harmonic voltage, while shunt APF effective in generate harmonic current to compensate harmonic current. Researchers have been developed and determine that shunt APF as a feasible solution to the problem created by nonlinear load. Shunt APF will operate at relative high switching frequency for generating the desired injection current that used to mitigate lower frequency harmonic order. Most of the techniques have their own difficulty level. In this project the instantaneous reactive power theory are selected as a method to implement in shunt active power filter.

In designing of inverter the most concern is to develop the harmonic less inverter. A lot of technique and topologies is developing to improve the harmonic of inverter. It is one of the popular devices used in high power medium- voltage (MV) drives. The MLI has an advantage of operation at high direct current (DC). The most significant advantage of MLI can generate output voltage with very low harmonic distortion. MLI also can solve the problem of high harmonic distortion that produced by the conventional inverter that have been used in energy conversion. The total harmonic distortion (THD) can cause the additional losses, overheating and overloading that can reduce the power quality of electrical system. There are various topologies of MLI but, the most common multilevel inverter topologies are Cascaded H-Bridge (CHB) inverter. In this project, the CHB is used to model and analyze the performance of MLI and tested with several of load. The used of CHB in this project is because the cascade MLI easy to control compare to other topologies such as Neutral Project Clamped (NPC) and Flying capacitor (FC).


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## 1.2 Problem statement

Due to extensive of used power converter and nonlinear load, power distribution systems suffer with the power quality issue. One of the power quality issues is harmonic. In Malaysia the development of solar system become highly demand with introduction of fit in tariff (FIT). In solar system, the most important part that need to be develop is inverter and to produce the harmonic less inverter will contribute to costly and complexity of the inverter.

To overcome these situations, the harmonic less MLI have been developed. Traditional method in designing the harmonic less inverter used PPF to mitigate harmonic, but PPF only eliminate at high frequency and it creates series/parallel resonance. Moreover, there is no effect in eliminated harmonic if nonlinear load connected to electrical system. If the inverter is connected to fixed load, it give good result in mitigates the harmonic. Unfortunately, the growth of dynamic load by the consumers bring the presents of harmonic. To overcome that issue the implementation of APF will cater the generation of harmonic.

## 1.3 Objective

The objectives of this project are:

1. To model a single phase shunt active power filter based on instantaneous reactive power theory.
2. To analyze the performance of single phase shunt active power filter connected with multilevel inverter.
3. To validate the design in reduce the harmonic for PWM cascaded multilevel inverter


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## 1.4 Scope

The scope of this study is to conduct the simulation on single phase shunt APF that combine with MLI. The CHB topologies used as MLI and operate by trinary, bipolar and unipolar switching method. The filter used control technology by using time domain technique. The method of obtain reference current is use the instantaneous reactive power theory. The simulation will conducted using MATLAB/Simulink software. The simulation block will be developed based on mathematical equation of p-q theory. The purpose of this simulation is to reduce the present of harmonic. Moreover, DC supply that used as source for MLI is assumed from photovoltaic solar as renewable energy system to determined performance of CHB-MLI with the effect of harmonic. Lastly, the different of load is tested which are fixed and dynamic load. It consists of R, RL and RC for fixed load while R, RL, and RC combine with rectifier consider as dynamic load. This variable load is used to determine the several change of THD that occur in the system.

## 1.5 Project Organization

This thesis contains of five chapters, starting with the introduction of research project which is about the effect of harmonic and implementation to mitigate the problem using shunt active power filter.

**Chapter 2** covers the literature review of this project and details about power quality, harmonic distortion and the effect, the harmonic problem method to overcome, type of MLI and the method to operate

**Chapter 3** discuss about on the switching technique to operate the cascaded multilevel inverter (MLI). There are many type of switching that use for MLI. For this chapter the


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trinary, bipolar and unipolar techniques are explaining more detail including the appropriate design to generate the switching waveform. Moreover, the main purpose of this project is to develop the single phase of active filter (APF). The power instantaneous technique that been used also discussed in this chapter. Moreover, the combination between MLI and APF also explain in general.

**Chapter 4** examined the simulation of cascaded multilevel inverter that combined with shunt APF. From the multiple type of switching method of CHB-MLI and instantaneous reactive power theory method for APF, the system is tested with different type of load. The result will shows the different of line current and load current before and after the connected of shunt APF.

**Chapter 5** is a discussion about the overall result of the simulation and prove the performance of shunt APF in order to improve the total harmonic distortion.


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# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter is discussing about the literature review of previous research. From the review will get more information that can be made to complete this project. All the new information taken from journals, papers, books and any academic articles that are related to this project will cite according to it belongs.

## 2.2 Power Quality

A latest innovative idea to make the life easy is by using the technology depends on the application of power electronics. Power quality (PQ) problem issues most concern nowadays. PQ problems can usually be traced from things like the starting and stopping of refrigeration compressors or air-conditioner motors, circuit overloads, harmonic currents created by electronic equipment, or grounding and wiring problems. Moreover, the increasing of non-linear load in electrical systems produces major causers of power quality problems [3]. With increasing of non-linearity, all these load cause disturbance in the voltage waveform.



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The degree of purity of power element can defined a power quality. It can classify that the performance of electrical system will work properly without any losses or the system is fully function form any interruption for the customer used [4]. Power supply, there are two type of frequency that has been used which is 50 Hz and 60 Hz. It also knows as fundamental frequency. If the presence of non-linear load in electrical system the frequency of voltage and current will be change. This is because the process multiplies of fundamental frequency with voltage or current frequency. It is also categorize as pollution to electrical system also know as harmonic distortion.

### 2.2.1 Harmonic in Electrical System

Harmonic is defined as a sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency [5]. In power system there are always had a present of harmonic. In early of 1890's harmonic were related on current and voltage waveform shape on transmission system. This shows that, it did not effect in industrial or commercial building due to the equipment was less sophisticated. Nowadays, the rapid increase number of electronic device has brought subject up-front. Due to this phenomenon, the harmonic creating devices also increase.

Since 1965, the harmonic creating devices that low cost, high efficiency semiconductor has increased in electronic power converters. Most of industry is use it in form of variable speed drive to control most of type of machinery. After the oil embargo and associates rapid increase in energy cost in 1973, the use of electronic power converter on larges system was essential. This is one of contributor on harmonic in power systems.

The presence of harmonic in electrical system is because present of non-linear load. Uninterruptible power supplies (UPS) system, solid state variable speed motor drives,


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rectifiers and personal computer are examples of non-linear load. Non-linear load occur when the impedance is not constant and the current produce is not proportional as voltage waveform. The current drawn from this load is not sinusoidal although it periodic. Typically, non-linear load from electronic switch power supplies and some device that involve in energy conversion. From this load, the consumer pays more in unused energy due to voltage and current distortion. If compare to linear load, the impedance is constant and the current is proportional to voltage because linear element in power system. Besides that, for linear load the consumers pay for unused energy from voltage distortion.

In a simple word harmonic is a summation of mathematical model of sinusoidal waveform that have been distorted. From the Fourier series equation of current and voltage represent in Equation 2.1 and Equation 2.2 , it is represent the additional of sinusoidal wave of various frequency that have been integer multiples of fundamental frequency.

$$i(t) = I_0 + \sum_{n=1}^{\infty} I_n \cos(nw_0 t + \emptyset_{I_n}) \tag{2.1}$$

$$v(t) = V_0 + \sum_{n=1}^{\infty} V_n \cos(nw_0 t + \emptyset_{V_n}) \tag{2.2}$$

Where,

$$\omega_0 = \frac{2\pi}{f}$$

To analyze the harmonic in power system, the present of distortion in waveform is important to determined. The Equation 2.3 and Equation 2.4 represent the total harmonic distortion (THD). The value of $V_1$ and $I_1$ are the fundamental voltage and current while $V_n$ and $I_n$ are the harmonic voltage and current.


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$$THD_V = \frac{\sqrt{\sum_{n=2}^{\infty}(V_{n,rms})^2}}{V_{1,rms}} x100\% \quad (2.3)$$

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty}(I_{n,rms})^2}}{I_{1,rms}} x100\% \quad (2.4)$$

### 2.2.2 Effect of harmonics

The increasing use of non-linear load devices will introduced a power quality issue in the form of harmonic distortion. The magnitude of this harmonic distortion varies with the nonlinear load distribution at various level of voltage in a system. The effect of generating harmonic that came from nonlinear load are facing a serious problem in the power system such as low power factor, increases losses, reduces the efficiency and increase the total harmonic distortion [6].

Harmonic distortion can cause poor power factor. Power factor problem will affect the overall power distribution system. The low of power factor may cause consumer to get heavy fines when the facility given is affecting the ability of efficiently the supply power. Due to distribution equipment overheating, random breaker tripping, or even sensitive equipment failure, it will produce increases of power losses [7].

Creating additional heating in power system components will reduce the expectancy of lifespan. Moreover, the false tripping or sensitive failure may result the equipment easy damage or blow for a no accepting reasons. In the long term, the problem due harmonic will break down an electrical system. All the electrical appliance or distribution equipment need to extra maintenance or change for a new. This particular will affect increasing of costs since harmonics affected in all power system equipment and high of electric bill [8].


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